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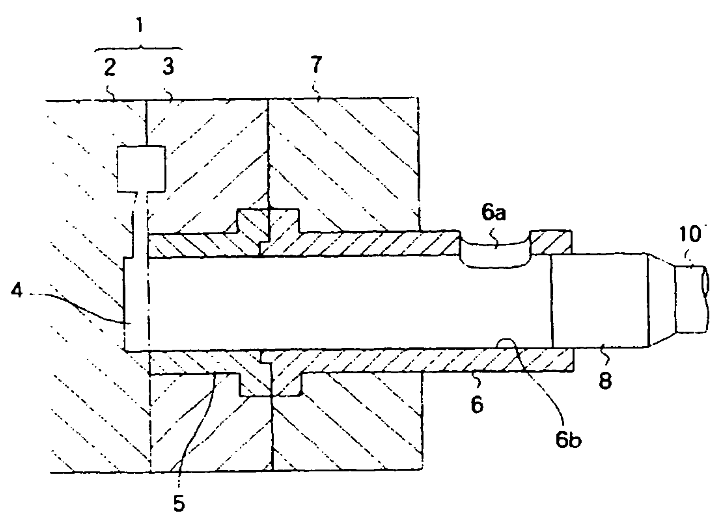
(54) Heat insulating alloy steel and die casting machine parts

(57) A heat insulating alloy steel contains 0.1 to 5.0 wt.% of C, 3.0 to 7.0 wt.% of Si, 5.0 to 18 wt.% of Ni, 0.5 to 8.0 wt.% of Cr, optionally at least one of less than 2.0 wt.% or less of Mn, 2.0 wt.% or less of Al and 2.0 wt.% of Mo, and the balance essentially of Fe. This heat insulating steel has a matrix metal structure with 30 % or more area ratio of a martensite phase. Further, a die casting machine part such as an injection sleeve or a pouring port bushing, having a surface making contact with an Al based molten metal, is made of a Fe base alloy containing 0.1 to 1.5 wt.% of C, 5.0 to 40 wt.% of Ni and 0.5 to 10 wt.% of at least one carbide forming element from: Cr, Mo, W, V, Nb, Ta, Ti and Zr. Such machine part comprises a surface layer portion including the surface making contact with the Al basedmolten metal, formed therein with a high density carbide layer as a dissolution resistance barrier.

FIG. 3



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Description

The present invention relates to parts of a die casting machine, and a die casting machine which are made of a heat insulating alloy steel useful as a structural material requiring thermal insulation, thermal shock resistance, wear resistance andcorrosion resistance.

The demand for injection-moulded metal parts manufactured by a die casting machine to have high qualities has become higher and higher. In order to meet such demand, it has become more important that the material characteristics of an injection sleeve, a chip or the like of a moulding device should have, in particular, high thermal insulation, high dissolution resistance to Al based molten metal as well as thermal resistance and high temperature mechanical strength.

Initially, the heat-insulation factor will be explained.

In the above-mentioned injection sleeve, it is likely that the temperature of molten metal lowers, and a solidified phase is produced in part when the temperature is lowered, resulting in lowering of the quality of an injection-moulded part. Accordingly, in order to prevent lowering of the temperature of the molten metal, thermal resistance of the injection sleeve, the chip or the like should be enhanced.

Present technology whereby injection speed is reduced to prevent occurrence of a gas-entrapping defect has become more prevalent and it is desired to prevent or minimise lowering of the temperature in the sleeve.

That is, recent die casting parts are ever increasingly required to have a high quality for example in automobile drive parts and brake parts. Entrapment of gas can be restrained by lowering the injection velocity. Lowering the injection velocity, however, causes lowering of the temperature of Al based molten metal, for example, in the injection sleeve so as to entrap a solidified layer (broken channel layer), which can cause defects such as lowering of strength or molten metal creasing. These problems also occur in a pouring port bushing of a runner system directly connected to the injection sleeve. In other words, the thermal insulation for the injection sleeve, the pouring port bushing or the like determines allowable ranges of appropriate injection conditions in a die casting machine. Accordingly, die casting machines including the injection sleeve are required with enhanced thermal insulation.

There has been proposed, to prevent lowering of the temperature in the injection sleeve, the use of an injection sleeve, a chip or the like, for die casting machines, which is made of ceramic materials or composite ceramic materials having low thermal conductivity. However. such an injection sleeve and a chip made of ceramic base materials have low shock resistance so their useful life is unstable, and they have a low expansion coefficient so that the difference in thermal expansion between them and metal members surrounding them is large. Thus, there has been such a problem that there is a substantial restriction to their use.

Further, these sleeves and tipsare expensive, further reducing their commercially availability.

In view of the above-mentioned difficulties, a metal material with excellent heat insulation, wear resistance and high temperature strength is desirable as a material from which an injection sleeve, a chip or the like of the die casting machine can be made.

Austenite type stainless steel such as SUS 304 or SUS 316 has been known as a metal material having low thermal conductivity. However, such austenite type materials are soft, and are insufficient for manufacturing precise dies in view of their processability, wear resistance, proof pressure and the like, and accordingly, have not been used for the present purpose. A diffusion process such as nitriding or carburizing has been tried to enhance the surface of the austenite group materials. However, the life of a hard layer obtained by nitriding and carburizing is reduced because the base material is soft. The occurrence of cracks due to thermal deformation and thermal shocks can also be caused since the thermal expansion coefficient of the austenite type materials is in a higher range of 18 to 22 x 10^{-6}/K at a temperature of about 573 K.

Accordingly, steel alloy is required with high thermal insulation, that is, thermal conductivity of less than 20 W/m·K, a thermal expansion coefficient in a range of about 9 to 17 x 10^{-6} at a temperature from a room temperature to 573 K, substantially equal to that of general tool steel, and a base hardness of greater than, for example, 300 Hv in mechanical strength, and which also has properties facilitating nitriding to obtain a nitriding depth substantially equal to that of an austenite type stainless steel.

An explanation is now given of the dissolution resistance for Al based molten metal.

A high corrosion resistance is required for an injection sleeve of a die casting machine. In particular, it is very important to enhance the dissolution resistance of an injection sleeve making contact with extremely active Al based molten metal in a process of die casting moulding an Al alloy part, and it is required to enable the sleeve to be formed with a stable nitride layer by nitriding or similar process as a countermeasure.

An Al based die casting product is manufactured by charging, under pressure with the use of a plunger, molten metal teemed from a sprue formed in the injection sleeve. into a cavity defined between a pair of dies. In a die casting machine of a cold chamber type adapted to be used for manufacturing such a die casting product, SKD61 (JIS, correspond to AISI-HI3 of U.S. Standard) tool steel is in general used as a material from which the injection sleeve making contact with the Al based molten metal is made. Incidentally, the above-mentioned injection sleeve made of SKD61

tool steel would react with the Al based molten metal to be eroded in a relatively short time. Accordingly, the injection sleeve is in general applied with nitriding at its bore surface which is adapted to make contact with the Al based molten metal. A nitride layer in which chromium based nitride is dispersed, having a thickness of about 50 to 200 μm is formed on a surface layer part of the SKD61 tool steel by nitriding in order to restrain the reaction with the Al based molten metal. However, this nitride layer is still eroded gradually during use, and should the nitride layer be consumed, the base material would be rapidly eroded, that is, the dissolution resistance cannot be reliably maintained for a long time.

Further, it is considered to subject the injection sleeve to a carburizing process, instead of the nitriding process. However, should a normal carburizing process be used, carbon would be diffused in the overall base material, that is, a carbonized layer which can restrain the reaction with the Al based molten metal would not be able to be formed.

A problem similar to the above-mentioned problem has occurred not only with the injection sleeve but also, for example, a pouring port bushing of a runner system connected to the injection sleeve, a die or a plunger chip. Accordingly, there is a requirement to enhance dissolution resistance of the parts directly making contact with the Al based molten metal and to enhance dissolution resistance durability.

Furthermore, accompanying lowering of the injection speed for enhancing die casting product quality, a defect such as lowering of strength or creasing of molten metal is likely to occur due to entrapment of a solidified layer. It is thus desired to increase the thermal insulation of the injection sleeve or to decrease its thermal conductivity to prevent such a defect from occurring. However, it is noted that lowering of thermal conductivity alone is not sufficient, since it is also desired to have a thermal expansion coefficient which can restrain, for example, thermal deformation and thermal shock.

The present invention has been devised to minimise or avoid the above-mentioned problems. One object of the present invention is to provide heat-insulating alloy steel which can satisfy the requirement of high thermal insulation, which has a thermal expansion coefficient substantially equal to that of general tool steel, a high base hardness. and which can obtain a nitriding depth equal to that of austenite type materials.

Further, another object of the present invention is to provide die casting machine parts with substantial dissolution resistance against Al based molten metal, and which can have a durable dissolution resistance, and a die casting machine using such parts with substantial and durable reliability.

Further, another object of the present invention is to provide die casting machine parts which can suppress defects such as lowered strength due to entrapment of a solidified layer or creasing of molten metal, by enhancing the thermal insulation, and which can restrain thermal deformation, thermal shock and the like, in addition to the above-mentioned dissolution resistance to the Al based molten metal, and to provide a die casting machine using such parts with substantial and durable reliability.

According to one aspect of the present invention, there is provided heat insulating alloy steel containing 0.1 to 0.5 wt.% of C, 3.0 wt.% to 7.0 wt.% of Si, 5.0 to 18 wt.% of Ni, 0.7 to 8.0 wt.% of Cr, and the balance consisting essentially of Fe. Unavoidable impurities may also be present.

Further, the heat insulating steel may further contain one or more of the following:
less than 2.0 wt.% (except 0 wt.%) of Mn, less than 2.0 wt.% (except 0 wt.%) of Al and less than 2.0 wt.% (except 0 wt.%) of Mo.

A die casting machine part according to a second aspect of the present invention is a part having a surface which in use will contact an Al based molten metal, and which part comprises a Fe base alloy containing 0.1 to 0.5 wt.% of C, 3.0 wt.% to 7.0 wt.% of Si, 5.0 to 18 wt.% of Ni, 0.5 to 8.0 wt.% of Cr, and the balance consisting essentially of Fe. Unavoidable impurities may also be present.

Further, according to the present invention, there is provided a die casting machine which is composed of a pair of dies one of which is movable, a pouring port bushing provided in a stationary one of the pair of dies, an injection sleeve connected to the pouring port bushing and serving as a teemed molten metal receiver and a pressurizing cylinder, a plunger for charging, under pressure, the Al based molten metal teemed in the injection sleeve, into a cavity defined between the pair of dies, and a drive mechanism for the plunger. wherein the die casting machine comprises at least one die casting machine part according to said second aspect, the die casting machine part being at least one selected from the group consisting of the pouring port bushing of the die, the injection sleeve and the plunger, which in use have a surface making contact with the Al based molten metal.

The heat insulating alloy steel, according to the present invention, has, as a base, a high concentration composition of Si and Ni which forms a solid solution of a high concentration with respect to Fe, and which brings about a martensite phase in a matrix metal structure at a casting step, and accordingly, it can exhibit excellent thermal insulation. Further, due to the martensite phase brought about in the matrix metal structure, a thermal expansion coefficient substantially equal to that of general tool steel and an excellent base hardness can be exhibited. Further, since a suitable quantity of Cr is contained, a sufficient nitriding depth can be ensured.

Explanation will be hereinbelow made of preferred embodiments the present invention by way of non-limiting example only.

A heat insulating alloy steel according to the present invention, comprises a Fe base alloy having following com-

position: 0.1 to 0.5 wt.% of C, 3.0 to 7.0 wt.% of Si, 5.0 to 18 wt.% of Ni, 0.5 to 8.0 wt.% of Cr and the balance of Fe.

The heat insulating alloy steel comprising the above-mentioned Fe based alloy has, as a base alloy, a high concentration composition of Si and Ni which forms a solid solution of high concentration with Fe, and which brings about a martensite phase in a matrix metal structure at a casting step. Further, it contains Cr in a suitable quantity for the purpose of ensuring sufficient nitriding depth. A detailed explanation is now made of the composition of the Fe base alloy.

C (carbon) is an element indispensable in the Fe base alloy for obtaining a high strength and a high hardness, and should be present at 0.1 wt.% or more to obtain these characteristics. However, if the content of C exceeds 0.5 wt.%, coarse Cr carbide or the like precipitated in the crystalline grain boundary becomes significant in lowering the thermal shock resistance, and accordingly, the preferable content of C is 0.5 wt.% or less. Further, C functions as an element for austenite-transforming in the high Ni-and Cr-containing alloy steel. Thus, to ensure a required amount of martensite phase, an excess amount of C is not desirable. Further, C is an interstitial solid solution element, and has such an effect that strain in the alloy crystal lattice can be enhanced, and the thermal conductivity can be lowered. A suitable content range can be determined in relation to the content of another alloy element, but it is preferable to have a high content within a range in which problems of formation of carbide, and of lowering of elongation do not occur.

Si (silicon) can form a solid solution up to 7 wt.% with Fe, and the atomic radius thereof is large in comparison with Fe so as to give such an effect of decreasing the thermal conductivity of the solid solution with Fe. Further, 3 wt.% or more of the content is preferable in order to ensure excellent thermal insulation. Further, Si exhibits a largely improved effect to counter high temperature oxidation. However, more than 7 wt.% of Si causes the formation of an intermetallic compound (M_3Si: where M is Fe or Ni) with Fe, Ni or the like, and accordingly, it rather causes an increase in the thermal conductivity and lowering of the mechanical properties. Thus, according to the present invention, the content of Si is set in a range of 3.0 to 7.0 wt.%. Further, as mentioned above, 3.0 wt.% or more of Si provides the heat insulating alloy steel according to the present invention with excellent thermal resistance and high temperature oxidation resistance.

Up to about 76 wt.%, Ni forms a solid solution in a wide range with Fe, and has an effect such as to lower the thermal conductivity of Fe, and the content should be 5.0 wt.% or more in order to obtain such properties. Further, as is well-known from the so-called Schaeffler's structure diagram shown in Fig. 1, the phase configuration of the base structure such as a rate between a martensite phase and an austenite phase is determined from the relationship between the Ni content (equivalent) and the Cr content (equivalent) within Fe. The Ni equivalent and the Cr equivalent in Schaeffler's structure diagram are represented by the following expressions:

$$\text{Ni Equivalent (wt.\%)} = \text{Ni wt.\%} + 30 \times \text{C wt.\%} + 0.5 \times \text{Mn wt.\%} \tag{1}$$

$$\text{Cr Equivalent (wt.\%)} = \text{Cr wt.\%} + 1.5 \times \text{Si wt.\%} + \text{Mo wt.\%} \tag{2}$$

However, in actual casting, segregation occurs during solidification, and accordingly, the zone of the martensite phase tends to be slightly wider than that shown in the Schaeffler's structure diagram.

As understood from Fig. 1, the composition of the Fe base alloy according to the present invention can bring about a martensite phase in the metal structure. The martensite structure has a large strain in a crystal lattice so as to obtain a low thermal conductivity and high hardness.

The Ni content is desired to be 18 wt.% or less in order to bring about such a martensite phase.

Further, within the range of the Ni content from 5.0 to 18 wt.%, it is preferable to set the area ratio of the martensite phase to 30 % or more of the matrix metal structure in view of the contents of C, Si and Mn, and the content of Cr, and the content of Mo as mentioned hereinbelow in order to lower the thermal conductivity and as well to obtain a satisfactory strength, rigidity (elastic modules), a wear resistance (hardness) and the like.

Cr is an element which improves the corrosion resistance, which forms, in particular, an intermetallic compound with Si in the surface layer to suppress the dissolution into Al based molten metal, thereby the dissolution resistance to Al based molten metal being greatly enhanced. Further, Cr exhibits an effect of improving the nitriding depth in steel, and accordingly, within the range of the content of Cr from 0.5 to 8.0 wt.%, it is possible to obtain a satisfactory nitriding depth. The Cr nitride layer exhibits an effect of improving the dissolution resistance against, for example, Al based molten metal.

However, Cr requires a suitable balance with coexisting alloy element such as C or Ni (equivalent) with respect to the formation of carbide, and the formation of a martensite phase, and accordingly, it cannot be contained so large, that is, the content of Cr is preferably to be in a range of 0.5 to 8.0 wt.%. If the content of Cr is 0.5 wt.% or less, the effect of improving the corrosion resistance and a sufficient nitriding depth cannot be obtained. Meanwhile, if the content exceeds 8.0 wt.%, the martensite phase cannot be obtained although it depends upon the content of the coexisting alloy elements such as C or Ni (equivalent), and further, an increase in quantity of formation of carbide is incurred so

as to lower the thermal shock resistance or the like.

In the heat insulating alloy steel having the above-mentioned composition of the Fe based alloy, the composition has a high concentration of Si and Ni, and is one to form a martensite phase, and accordingly, it is possible to aim at lowering the thermal conductivity and obtaining a suitable thermal expansion coefficient and a satisfactory base hardness. Further, a nitriding depth substantially equal to that of austenite type stainless steel can be obtained due to the presence of Cr.

In particular, by setting suitable Ni equivalent and Cr equivalent so that 30 % or more (area ratio), preferably more than 70% of the base structure has an austenite phase, the thermal conductivity can be lowered, and as well, the strength, the rigidity (elastic modulus) and the wear resistance (hardness) can be further enhanced.

Further, since the martensite phase has a low thermal expansion coefficient in comparison with the austenite phase, a thermal expansion coefficient in a temperature range from a room temperature to 573 K, which is a low value of about 9 to 17 x 10^{-6}/K which is substantially equal to that of general tool steel can be obtained, and accordingly, it is excellent in thermal shock resistance and thermal fatigue resistance.

The heat insulating alloy steel according to the present invention can aim at improving the properties by adding Mn, Mo or Al in addition to the above-mentioned basic alloy elements.

Mn exhibits an effect of improving the mechanical strength, but if the content thereof is so large, the formation of carbide cannot be avoided, and further serves as element which forms an austenite phase. Thus, the content is set to 2.0 at the upper limit, the effect by adding Mo becomes significant from about 0.5 wt.%.

Mo exhibits an effect of improving the corrosion resistance of Fe based alloy containing Cr, Ni and Si. Further, it contributes to improve the high temperature strength and the temper brittleness. However, in view of restraining precipitation of coarse carbide, the content of Mo is set to be 2.0 wt.% or less. Further, the effect by adding Mo is significant from about 0.1 wt.%.

Al exhibits an effect similar to that of Si, that is, an effect of enhancing the heat insulation and an effect of improving a high temperature oxidation characteristic. However, it is likely to form a compound with other metal elements in comparison with Si. In view of this fact, the content of Al is set to be 2.0 wt.% or less. Further, the effect by adding Al is significant from about 0.1 wt.%.

The heat insulating alloy steel having the above-mentioned Fe based alloy composition, can be manufactured by using a general casting method, and a metal structure bringing about a martensite phase at a casting step, and in particular, a metal structure bringing about 30 % or more, as an area ratio, of the martensite phase can be obtained. Thus, the metal structure in which 30 % or more, as an area ratio, of the martensite phase is brought about, can exhibit excellent characteristics as mentioned above, but by further applying a tempering process, the tensile strength, the durability, the elongation, the hardness and the like can be enhanced. A suitable tempering temperature as will be detailed in an embodiment explained hereinbelow, is in a range of 523 to 723 K.

The heat insulating alloy steel according to the present invention, can satisfy the above-mentioned alloy composition, and can practically have a thermal conductivity of 20 W/m·K in a temperature range of a room temperature to 573 K, and a thermal expansion coefficient of 9 to 17 x 10^{-6}/K in the same temperature range, can obtain a hardness of 300 Hv, and a tensile strength of 400 N/mm^2.

Further, the heat insulating alloy steel according to the present invention can show excellent high temperature oxidation resistance and is thereby useful as a heat insulating material at

a high temperature. Further, a nitriding depth substantially equal to that of austenite type stainless steel can be obtained, and it can have excellent dissolution resistance properties even though it makes contact with a wear resistant member or Al based molten metal.

In view of these facts as mentioned above, the heat insulating alloy steel according to the present invention, is suitable for components constituting a die casting machine, including an injection sleeve and a chip, and in particular, a component material for a die casting machine part having a surface making direct contact, in use, with Al based molten metal, a material for dies in the die casting machine, and particularly a material for dies for fine and precise products.

Next, explanation will be made of embodiments of a die casting machine according to the present invention, and of parts thereof, by way of non-limiting examples only.

Fig. 2 is a schematic view which shows an embodiment of a die casting machine,

Fig. 3 is an enlarged view which shows an essential part of the die casting machine.

With reference to these figures, a pair of dies 1 is composed of a movable die 2 and a stationary die 3 which define therebetween a cavity 4. A pouring port bushing 5 is provided being connected to the cavity 4, formed in the stationary die 3. Further, the pouring port bushing 5 is connected thereto with an injection sleeve 6 which is supported by a platen 7.

A teeming port 6a is formed in the injection sleeve 6, through which Al base molten metal is charged. A plunger

chip 8 is movably located in the injection sleeve 6, and is linked to a plunger rod 10 which is driven by a plunger drive mechanism such as a hydraulic cylinder 9. The Al based molten metal charged through the teeming port 6a, is pressurized and charged into the cavity 4 by the plunger chip 8 when the hydraulic cylinder 9 is operated.

The movable die 2 can be moved by a die moving mechanism such as a hydraulic cylinder 11 or the like. When the movable die 2 is moved in a predetermined direction, a die casting product produced in the cavity 4 is discharged from the dies by means of a secured push-rod 12.

In the above-mentioned die casting machine, the injection sleeve 6 having its inner peripheral surface 6b serving as a surface making contact with Al based molten metal is made of Fe based alloy which contains 0.1 to 0.5 wt.% of C, 3.0 to 7.0 wt.% of Si. 5.0 to 18 wt.% of Ni, and 0.5 to 8.0 wt.% of Cr.

The injection sleeve has a surface layer part including the inner peripheral surface 6b as the surface making contact with Al based molten metal, which is formed therein with a high density carbide layer due to selective diffusing reaction with Al based molten metal. This high density carbide layer serves as a dissolution resistance barrier layer. The injection sleeve 6 is one embodiment form of the die casting machine part according to the present invention.

That is, the surface layer part including the inner peripheral surface 6b of the injection sleeve 6 is formed therein with a self-repairable high density carbide layer formed as a dissolution resistance barrier layer due to selective diffusion reaction with Al based molten metal. The injection sleeve 6 is formed of the Fe based alloy containing Ni, C and the carbide forming element as base components from which the self-repairable high density carbide layer is formed. Explanation is now provided of a process of forming a dissolution resistance barrier layer formed of the above-mentioned high density carbide layer with reference to Figs. 4A and 4B.

Referring to Fig. 4A, when the inner peripheral surface 6b of the injection sleeve 6 made of Fe based alloy 21 as mentioned above, makes contact with Al based molten metal 22, Ni having a high diffusion coefficient in the Al based molten material 22 is eluted preferentially from the Fe based alloy 21 into the Al based molten metal, and then Fe is eluted. Due to the selective elusion (selective diffusion) of Ni and Fe, a zone 23 in which C and the carbide forming element are present at high densities remains in the surface layer part of the Fe based alloy 21.

The surface layer part of the inner peripheral surface 6b side of the injection sleeve 6 having the zone in which C and the carbide forming element are present at high densities is heated up to a high temperature, for example, in a range from 923 to 973 K. by heat from the Al based molten metal 22, and accordingly, the reaction of formation of carbide is rapidly progressed. If the density of the carbide becomes higher than a certain degree, elution of Ni and Fe from the Fe based alloy 21 into the Al based molten metal 22 ceases.

That is, as shown in Fig. 4B, a layer which is obtained by diffusing carbide in the surface layer part including the inner peripheral surface 6b of the injection sleeve 6, that is, the high density carbide layer 24 is formed as the dissolution resistance barrier layer, and accordingly, it is possible to prevent dissolution damage from being further progressed.

Even though the dissolution resistance barrier layer formed of the above-mentioned high density carbide layer 24 is consumed due to sliding contact with the plunger chip 28 during use of the die casting machine or the like, a new high density carbide layer 24 can be formed by making contact with the Al based molten metal through the above-mentioned process. Thus, the dissolution resistance barrier layer formed of the high density carbide layer 24 is continuously formed as a self-repairable layer.

The high density carbide forming layer 24 as the dissolution resistance barrier layer is preferably formed having a thickness of about 50 to 240 μm. If the thickness of the high density carbide layer 24 is less than 50 μm, there would be a risk of not sufficiently serving as the dissolution resistance barrier layer. Meanwhile, even if the barrier is formed having a thickness exceeding 200 μm, no higher effect could be obtained, and as well, peel-off of the high density carbide layer 24 from the mother metal material would be caused. The thickness of the high density carbide layer 24 can be controlled by e.g. the Ni content.

During the above-mentioned reaction. in the case of Al molten metal containing Si, such as ADC 12 Al alloy (JIS), (corresponding to ASTM-B85-84 Material Designation 383.0, USA) containing 12 % of Si, Si is eluted into the Fe based alloy 21 prior to Ni, and thereafter the elution of Ni is progressed. Accordingly, a Si- rich layer is formed at the same position as that of the zone 23 in which C and the carbide forming element are present at high densities in an overlapping manner. Since carbide is formed even in the zone in which the C, the carbide forming layer and the Si are present at high densities, a dissolution resistance barrier can be formed, similar to the case of Al molten metal having a low content of Si.

The inner peripheral surface 6b of the sleeve 6 can be formed therein with a self-repairable dissolution resistance barrier as mentioned above, and accordingly, a low dissolution resistance speed can be always maintained. That is, even though the layer is consumed, a new barrier layer is formed, and accordingly, a satisfactory dissolution resistance can be maintained for a long time, thereby it is possible to greatly enhance useful life of the injection sleeve 6.

As to the parts in which a self-repairing dissolution resistance barrier layer can be formed, such is effective not only on the injection sleeve but also on the pouring port bushing 5 having a surface making contact with the Al based molten metal. That is, the pouring port bushing is made of similar Fe base alloy, and a dissolution resistance barrier layer formed of a high density carbide forming layer can also be formed with a self-repairable surface which makes

contact with the A1 based molten metal so as to enhance the dissolution resistance of the pouring port bushing against the Al based molten metal, and the dissolution resistance thereof can be maintained for a long time.

As a metal alloy which can enhance the dissolution resistance to the Al based molten alloy by forming a high density carbide layer using selective diffusion reaction as mentioned above, the following metal alloys are given in addition to the above-mentioned heat insulation steel alloy. These alloys are also effective as a die casting machine part having a surface making contact with the Al based molten alloy.

That is, a heat insulation metal alloy to enable the self-repairable formation of the dissolution resistance barrier formed of the above-mentioned high density carbide layer 24, in the injection sleeve 6, the pouring port bushing 5 or the like is an Fe based alloy containing 0.1 to 1.5 wt.% of C, 5.0 to 40 wt.% of Ni, 0.5 to 10 wt.% of at least one kind of carbide forming element selected from a group consisting of Cr, Mo, W, V, Nb, Ta, Ti and Zr.

In this Fe based alloy, Ni and Fe selectively are eluted by contacting with an Al based molten alloy, and then a zone in which C and the carbide forming element are present at high densities remains in the surface layer part including that surface which, in use, contacts the Al based molten alloy. Since the zone containing high density C and the carbide forming element is heated at a high temperature by heat from the Al based molten metal, the reaction of carbide forming is rapidly progressed, whereby a high density nitride layer is formed. The high density nitride layer serves as a dissolution resistance layer, and acquires self-repairability during the process previously mentioned. Thus, the dissolution resistance can be maintained for a long time.

Further, the Fe based alloy composition containing 0.1 to 0.5 wt.% of C, 3.0 to 7.0 wt.% of Si, 0.5 to 1.0 wt.% of Mn, 5.0 to 15.0 wt.% of Ni, 2.0 to 8.0 wt.% of Cr, and 0 to 1.0 wt.% of Mo for the Fe based alloy used in the die casting machine part enables formation of a martensite phase. This Fe based alloy in which a martensite phase was brought out can obtain a stable dissolution resistance for a long time together with excellent heat insulation and a desirable thermal expansion coefficient.

It is noted here that C is an important element for forming carbide such as Cr carbide which has a low wettability to Al based molten metal, and no dissolution damage so that its content is required to be 0.1 wt.% or more in order to form a dissolution resistance barrier layer formed of a high density carbide layer. However, in order to ensure thermal fatigue resistance, shock resistance and process ability for the injection sleeve 6, the pouring port bushing 5 or similar part, it is preferable to prevent coarse carbide having a particle size of greater than 30 μm from existing in the grain boundary or the matrix of the Fe based alloy, and accordingly, the content of C is such as to ensure it is not excessive. Specifically, the content is 1.5 wt.% at the upper limit in the case of Fe base alloy containing 2 to 10 wt.% of a carbide forming element such as Cr.

Ni is an element which can realize selective elution into Al based molten metal, causing the formation of the dissolution resistance barrier layer, and accordingly, the content of Ni is set to be 5 wt.% or more in order to form the dissolution resistance barrier layer with a thickness of about 50 to 200 μm. However, if the content of Ni exceeds 40 wt.%, the segregation of Ni becomes significant.
Thereby the zone in which C and the carbide forming element are present at high densities is unevenly formed in the surface layer, and accordingly, it can not function well as the dissolution resistance barrier layer. Thus, the content should be 40 wt.% or less.

At least one kind of element selected from a group consisting of Cr, Mo, W, V, Nb, Ta, Ti and Zr can show relatively rapid elution into an Al based molten metal, and form carbide, that is, it forms the dissolution resistance barrier layer through the above-mentioned process. A suitable content of the element(s) which can prevent coarse carbide in the grain boundary or particles within the metal structure of the Fe based alloy, is determined by consideration of the content of C. In such a condition that the content of C is 0.1 to 1.5 wt.%, the content of the element is set to be 0.5 wt.% or more, preferably in a range of 2.0 to 10 wt.%. That is, in order to form the dissolution resistance barrier layer formed of the high density carbide layer, the content is set to be 2.0 wt.% or more, but in order to prevent coarse carbide from existing, the content is set to be 10 wt.% or less. Of the above-mentioned elements, Cr is a typical carbide forming element, and is preferably present in a quantity which avoidsthe precipitation of carbide so that a thick dissolution resistance barrier layer can be formed, and accordingly it is particularly preferable.

The injection sleeve 6, the pouring port bushing 5 and similar parts made of the Fe based alloy which satisfies the above-mentioned composition range can obtain a satisfactory dissolution resistance. However, in order to satisfy required properties such as low thermal conductivity, strength, a suitable thermal expansion coefficient in addition to the dissolution resistance, it is preferable to use Fe based alloy of 0.1 to 0.5 wt.% of C, 3.0 to 7.0 wt.% of Si, 0.5 to 2.0 wt.% of Mn, 5.0 to 15 wt.% of Ni, 0.5 to 8.0 wt.% of Cr, 0 to 2.0 wt.% of Mo and the balance apart from any inevitable impurities consisting essentially of Fe. 0.1 to 1.0 wt.% of at least one element selected from Nb, Ti and V can be used, instead of Mo.

The Fe based alloy having the above-mentioned composition can enhance the thermal insulation or can lower the thermal conductivity, and can provide a metal structure in which a martensite phase is brought about. Further, a low thermal conductivity which is 20 W/m·K or less can be obtained. Further, if the structure mainly having a martensite phase is used as the matrix structure of the Fe based alloy, it is possible to aim at enhancing the strength and the

hardness, and further to control the thermal expansion coefficient in a suitable range. Specifically, a thermal expansion coefficient of not more than about 18 x 10^{-6}/k in a temperature range from a room temperature to 573 K can be obtained. Meanwhile, in a structure mainly having an austenite phase, the thermal expansion coefficient in the temperature range or a room temperature is as high as about 18 x 10^{-6}/k, as mentioned above, and accordingly, if this structure is used for a sleeve and dies in a die casting machine, cracks are likely to occur, being caused by deformation and thermal shock. It is noted that the tensile strength of tool steel used in general for a sleeve and dies in a die casting machine can be converted into a hardness (high strength = high hardness). It can be conveniently evaluated by reference to its hardness.

We now provide an explanation of the reasons and the range of addition of the elements in the Fe based alloy which can improve low thermal conductivity, strength and a suitable thermal coefficient in addition to the above-mentioned dissolution resistance.

Si is an element contributing to lowering of the thermal conductivity of the Fe based alloy, and its content is large in comparison with general Fe based alloy. In order to maintain a thermal conductivity of not more than 20 W/m·K at 573 K. under the above-mentioned condition, it is preferable to set the content of Si to be 3.0 wt.% or more. However, if it exceeds 7 wt.%, an intermetallic compound would be formed with Ni, and accordingly, the thermal conductivity becomes significantly affected. Thus, the content of Si is preferably 7 wt.% or less.

Mn can contribute to lowering the thermal conductivity since most of the adding quantity thereof causes solid solution with Fe, in addition to such an effect that the strength of the alloy can be enhanced. However, if the content exceeds 2 wt.%, coarse carbide is likely to precipitate, and accordingly, it is preferably set to be 2 wt.% or less.

Mo exhibits effects similar to that of Mn, and further, the content thereof is preferably set to be not more than 2.0 wt.% in order to restrain precipitation of coarse carbide, similar to Mn. Further, this also exhibits an effect of avoiding tempering brittleness when nitriding Mn-containing Fe based alloy at a temperature from about 773 to 973 K.

C, Ni and Cr cause effects when the matrix structure of Fe based alloy is turned into a structure mainly having a martensite phase in addition to the above-mentioned roles, and accordingly, their contents are further limited within an appropriate range.

That is, as mentioned above, in view of the contents of the elements, the contents of Cr, Ni, Cr are adjusted so as to select a composition which brings about a martensite phase, or a composition which gives a structure mainly having a martensite phase.

For example, in order that the matrix of Fe based alloy has a structure including 50 % or more, as an area ratio, of a martensite phase, the contents can be roughly estimated from Schaeffler's structure diagram as shown in Fig. 1 in accordance with the Ni equivalent and the Cr equivalent which are represented by the above-mentioned expressions (1) and (2).

However, the solidified structure of the injection sleeve 6 and the pouring port bushing 5 or similar part having a thickness of about 15 to 20 mm is deviated from the Schaeffler's structure diagram. The actual solidified structure of the injection sleeve 6, the pouring port bushing 5 or the like, is shifted toward a low Ni equivalent and a low Cr equivalent.

By forming the injection sleeve 6 and the pouring port bushing 5 from the Fe based alloy having a low thermal conductivity and a low thermal expansion, it is possible to restrain the temperature of Al based molten metal from being lowered by the injection sleeve 5 and the pouring port bushing 5 even though the injection velocity is lowered. Accordingly, occurrence of such defects as lowering of strength, creasing of molten metal or the like caused by entrapment of the solidified layer (broken chill layer) can be minimised or even avoided. Further, it is possible to prevent occurrence of cracks or the like due to thermal deformation and thermal shocks brought about by a low thermal expansion. From this fact. the reliability of the die casting machine can be further enhanced.

In order that the invention may be further illustrated, reference is also made to the accompanying drawings and to the subsequent description of the preferred embodiments by way of non-limiting examples.

Fig. 1 is a view showing a Schaeffler's structure diagram exhibiting phase structures given by Ni equivalent and Cr equivalent in Fe based alloy;

Fig. 2 is a partly sectioned schematic view illustrating an arrangement of a die casting machine in an embodiment form of the present invention;

Fig. 3 is an enlarged view illustrating an essential part of the die casting machine shown in Fig. 2;

Figs. 4A and 4B are views typically showing a forming process of a dissolution resistance barrier layer in a die casting machine part according to the present invention;

Fig. 5 is a view showing relationship between tempering temperature and tensile strength of a heat insulating alloy steel according to the present invention;

Fig. 6 is a view illustrating a shape of Al alloy product manufactured in an embodiment of the present invention; and

Figs. 7A, 7B and 7C are views showing results of measurement for distribution of concentrations of Cr, Ni, and Fe in a surface layer part in the inner peripheral side of the injection sleeve in an embodiment of the present invention.

Embodiments of the present invention are now described with reference to these drawings by way of non-limiting example only.

Embodiments 1 to 7 and Reference Examples 1 to 8

The embodiments of heat insulating alloy steel according to the present invention are described initially.

Mild steel, Ni, Fe-Cr alloy, Fe-Mn alloy, Fe-Mo alloy, and a carburization material (C) were melted in an induction furnace so as to obtain alloy compositions shown in Table 1 and were discharged at 1873 K. After adding Al in a ladle as necessary, the molten metal was then cast at a temperature of 1723 to 1773 K into one inch block moulding dies for a tensile test piece so as to obtain alloy steel samples.

It is noted that the heat insulating alloy steel according to the present invention has a tendency such that Ni and Si is segregated in a dendrite gap within the structure of a casting. Accordingly, an austenite phase is likely to occur in a part of the dendrite gap area. In such case that the control of the area ratio of the martensite phase as desired is required, solution heat treatment for heating the alloy steel up to a temperature of 1,000 to 1,200 °C is applied so that component elements such as Ni. Si are made to be uniform. Accordingly, it can be controlled as desired to a quantity for creating the austenite phase from component compositions. The cooling speed in this solution heat treatment, is desired to be higher than an air cooling speed, and in particular, in the case of quenching into oil or water, tempering heat treatment is carried out at a temperature from 200 to 650 °C, whereby the structure can be stabilized.

Component compositions of such alloy steel samples obtained are shown in Table 1. Area ratios of martensite phases in the matrix metal structure of these alloy steels were measured, and the results are also show in Table 1. It is noted that comparative examples in this table, are exemplified for comparison with the present invention, being outside the scope of the alloy compositions according to the present invention.

The properties of the above-mentioned alloy steels were evaluated as follows. At first, the thermal conductivity (573 K) of the metal alloy steels after casting, averaged thermal expansion coefficient in a temperature range from a room temperature to 573 K, hardness, tensile strength as mechanical property, and corrosion resistance (dissolution resistance) against Al molten metal were measured and evaluated respectively. Results thereof are shown in Table 2. It is noted that the evaluation of the corrosion resistance (dissolution resistance) against the Al molten metal was carried out in such a way that after the alloy steel samples were subjected to gas nitriding treatment under such a condition as at a temperature of 853 K for 30 hours, the alloy steel samples were dipped in pure Al molten metal at 953 K, then, after 10 and 100 hours elapsed, they were picked up, and after an Al deposited layer was removed from the surfaces thereof by caustic soda, variations in weight (dissolution loss) were measured.

Table 1

	Alloy Composition (weight %)								Martensite Phase
	C	Si	Mn	Ni	Cr	Mo	Al	Fe	Area Ratio (%)
Example									
1	0.2	5.5	1.0	9	4.0	0.5	--	balance	89
2	0.3	5.0	0.5	5	8.0	0.2	--	balance	30
3	0.1	3.0	0.8	18	1.0	--	--	balance	45
4	0.5	4.0	0.6	9	0.5	0.2	--	balance	85
5	0.2	5.0	1.0	10	3.0	2.0	1.0	balance	95
6	0.3	5.0	1.5	10	4.0	--	2.0	balance	60
7	0.1	7.0	1.0	8	5.0	0.2	--	balance	80
Comparative Example									
1	0.05	2.5	1.0	10	5.0	0.2	--	balance	100
2	0.8	5.0	1.0	4.5	4.0	0.2	--	balance	10
3	0.2	8.0	1.0	10	0.5	0.2	--	balance	80
4	0.5	5.0	2.5	10	4.0	0.2	--	balance	0
5	0.3	5.0	1.0	20	4.0	0.2	--	balance	0
6	0.3	4.5	1.0	10	10.0	0.2	--	balance	0
7	0.3	4.5	1.0	10	4.0	3.0	--	balance	90
8	0.3	5.0	1.0	10	4.0	0.2	3.0	balance	85

Table 2

	Thermal conductivity (573K)	Thermal expansion coefficient (RT ~ 573K)	Hardness	Tensile strength	Dissolution loss damages weight rate (%) in Al	
	(W/m·K)	(x 10^{-6}/K)	(Hv)	(N/mm^2)	10 H	100 H
Example						
1	14.1	12.6	500	573	0	0
2	15.5	16.0	300	402	0	0
3	12.5	17.0	386	475	0	0
4	20.0	9.3	522	612	0	4.2
5	14.5	15.0	540	573	0	0
6	14.0	15.2	488	510	0	0
7	15.3	13.9	502	545	0	0
Comparative Example						
1	26.2	12.7	532	375	0	0
2	20.7	16.2	286	325	0	0
3	19.4	16.5	388	505	20	84
4	17.2	19.0	226	356	0	0
5	15.4	19.6	230	285	0	0
6	15.2	18.0	302	245	0	0
7	21.1	16.2	436	537	0	0
8	23.5	17.1	504	317	7	36

As clearly understood from Table 2, any of the alloy steel samples in the embodiments has a thermal conductivity less than 20 W/m·K at 573 K, and has high thermal insulation. Further, the tensile strength is higher than 400 N/mm^2 and a hardness of higher than 300 Hv, that is, it has excellent mechanical properties. Further, the thermal expansion coefficient in the temperature range from a room temperature to 573 K is in a range of 9 to 17 x 10^{-6}/K. that is, it has excellent thermal deformation resistance and thermal shock resistance. In the evaluation of the corrosion resistance (dissolution resistance) against the Al molten metal, it was confirmed that any of the alloy steels in the embodiments has a satisfactory nitriding depth, and exhibits a corrosion resistance which is excellent in view of the dissolution resistance against the Al molten metal.

On the contrary, the alloy steel samples in the comparative examples having alloy compositions which are outside the alloy composition range of the present invention, are inferior in view of either one of the thermal conductivity, the thermal expansion coefficient, the mechanical strength and the Al dissolution resistance, as clearly understood from Table 2.

Further, the heat-insulating alloy steel according to the present invention, has improved mechanical properties such as tensile strength by application of tempering heat treatment.

Fig. 5 shows tensile strengths of the alloy steel samples in the embodiments after application of tempering heat treatment at various temperatures. As understood from Fig. 5, it is preferable to set the tempering temperature in a range of 523 to 723 K (250 to 450°C). It is noted that the area ratio of the martensite phase increases by 10 %, due to decomposition of a residual austenite phase through the tempering heat treatment (for about 2 hours) in this temperature range, but the thermal properties do not vary greatly.

As mentioned above, the heat insulating alloy steel according to the present invention, can realize a high thermal insulation, and as well has a thermal expansion coefficient substantially equal to that of general tool steel, an excellent base hardness, and a nitriding depth substantially equal to that of austenite type materials. Further, it is suitable as a structural material requiring thermal insulation, thermal shock resistance, wear resistance, and corrosion resistance.

Embodiments of die casting machine parts according to the present invention are now described by way of non-limiting examples.

Examples 8 to 13, and Comparative Examples 9 to 10.

Fe base alloys having components shown in Table 3 were melted in a high frequency induction furnace, and were cast with the use of a flan sand mould so as to produce an injection sleeve 6 having a shape shown in Fig. 3, having an outer diameter of 70 mm, an inner diameter of 50 mm and a length of 250mm, and a pouring port bushing 5 having an outer diameter of 70 mm, an inner diameter of 50 mm and a length of 100 mm. The properties and metal structures of the Fe based alloys shown in Table 3 are as shown in Table 4.

It is noted that the comparative example 9 is SKD61 as a conventional material, and the comparative example 10 is Fe base alloy having a composition outside the composition range of the present invention, an injection sleeve 6 and a pouring port bushing 5 according to the present invention being produced similarly.

The injection sleeve 6 shown in Fig. 3 is cylindrical, and is formed at its one end with a teeming port 6a, and is provided at its other end with a flange. Further, the pouring port bushing 5 is connected to the injection sleeve 6 to enhance lowering the temperature of Al based molten metal. Further, they are parts likely to encounter dissolution loss since they make contact with the Al based molten metal at a high temperature under pressure.

The injection sleeve 6 and the pouring port bushing 5 were incorporated in the die casting machine shown in Fig. 2 for testing and evaluation.

Specifically, a die casting product 31 having a shape shown in Fig. 6, was moulded from ADC12Al alloy, and its several properties were evaluated.

The property evaluation was carried out as follows: The injection sleeve was cut after 2,000 shots, and micrography of the surface layer was carried out so as to examine the presence of formation of a high density carbide layer, the presence of dissolution damage to the injection sleeve, the presence of deformation and the occurrence of cracks at the inner peripheral surface of the sleeve. Further, a section of the Al alloy part was observed so as to check the presence of a broken chill layer, and further, the presence of creasing of molten metal was examined by observing the external surface of the part. Results thereof are shown in Table 5.

Table 3

	Alloy composition (weight %)							Condition of heat treatment
	C	Si	Mn	Ni	Cr	Mo	Fe	
Example								
8	0.22	5.0	0.8	10.1	4.5	0.2	balance	Tempering of 573K
9	0.16	4.6	1.0	12.2	3.6	0.4	balance	Tempering of 573K
10	0.34	4.9	0.5	8.7	5.2	--	balance	Tempering of 573K
11	0.12	3.5	0.6	15.0	5.8	0.4	balance	Tempering of 573K
12	0.50	4.9	0.5	5.0	2.0	--	balance	Tempering of 573K
13	0.27	6.7	0.9	9.0	3.6	1.0	balance	Tempering of 573K
Comparative Example								
9	0.32	0.9	0.43	(V:0.9)	5.2	1.2	balance	Tempering of 1293K
10	0.11	5.0	0.5	11.3	0.1	0.2	balance	Tempering of 573K

Table 4

	Thermal conductivity	Thermal expansion coefficient	Hardness	Martensite phase
	(573K)	(RT ~ 573K)	(Room temperature)	Area ratio
	(W/m·K)	($\times 10^{-6}$/K)	(Hv)	(%)
Example				
8	17.0	11.3	520	100
9	16.8	12.0	486	100
10	18.7	11.4	547	100
11	16.2	12.6	460	95
12	19.3	15.3	366	55
13	15.6	13.8	465	80
Comparative Example				
9	34.5	10.5	486	100
10	16.5	16.3	532	100

Table 5

	Formation of high density Cr carbide layer	Dissolution damage (2000 shot)	Contamination by broken chill layer	Occurrence of creasing of molten Al	Occurrence of deformation or crack (2000 shot)
Example					
8	Yes	No	No	No	No
9	Yes	No	No	No	No
10	Yes	No	No	No	No
11	Yes	No	No	No	No
12	Yes	No	No	No	No
13	Yes	No	No	NO	No
Comparative Example					
9	No	dissolution damage	Yes	Yes	No
10	No	dissolution damage	No	No	No

In the injection sleeves in the examples 8 to 13, a layer in which chromic carbide having a thickness of 100 to 300 μm was densely formed was confirmed in the surface layer part of the inner peripheral surface. Accordingly, no dissolution damage was found in the injection sleeve and the pouring port bushing even after 2,000 shots.

Results of measurement of distributions of concentrations of these elements in the surface layer part of the injection sleeve in the example 8 are shown in Figs. 7A, 7B and 7C. Relative concentrations of the components are taken on the ordinate, and positional relationships between Al alloy and the injection sleeve are taken on the abscissa. As understood from these figures, Ni and Fe are selectively eluted into the Al alloy, and on the contrary, a high density Cr carbide layer is created in the surface layer of the injection sleeve.

Further, these have a matrix metal structure mainly having a martensite phase at a step after casting, and already have a relatively high hardness. Further, a hardness of Hv 350 to 550 could be obtained by tempering them at a temperature of 573K. Further, the thermal conductivity at 573 K is not more than 20 W/m·K, and accordingly, it is clear that entrapment of a broken chill layer and occurrence of creasing of molten metal can be restrained.

Meanwhile, the comparative example 9 using SKD61 as a conventional material, contains C and Cr sufficiently, but does not contain Ni. and accordingly, no Cr carbide layer is formed in the surface layer.

The comparative example 10 has a low Cr content of 0.1 wt.%, and accordingly, no Cr carbide layer is formed in the surface layer. It was found that the injection sleeve made of such alloy easily suffered dissolution damage caused by ADC12Al molten alloy.

As mentioned above, the die casting machine parts according to the present invention, exhibit excellent dissolution resistance against Al based molten metal, and moreover such excellent dissolution resistance can be maintained for a long time. Further, since the thermal insulation is enhanced, occurrence of defects such as reduced strength caused by entrapment of a solidified layer, and creasing of molten metal can be restrained. In addition, it is possible to prevent occurrence of thermal deformation, and cracks caused by thermal shocks. Die casting machinesusing such die casting machine parts according to the present invention, can produce Al based die casting products of high quality and high reliability economically.

Claims

1. A heat insulating alloy steel comprising:
   0.1 to 0.5 wt.% of C;
   3.0 to 7.0 wt.% of Si;

5.0 to 18 wt.% of Ni;
0.5 to 8.0 wt.% of Cr; and the balance essentially of Fe.

2. A heat insulating alloy according to claim 1, wherein the alloy steel further comprises at least one selected from the group consisting of more than 0 to 2.0 wt.% of Mn, more than 0 to 2.0 wt.% of Al, and more than 0 to 2.0 wt.% of Mo.

3. A heat insulating alloy according to claim 1 or 2, having a martensite phase which has an area ratio of 30 % or more in a matrix metal structure of the alloy steel.

4. A heat insulating alloy according to any preceding claim, having a thermal conductivity of 20 W/m.K or less in a temperature range from a room temperature to 573K, and a thermal expansion coefficient of 9 to 17 x 10^{-6}/K in said temperature range.

5. A heat insulating alloy according to any preceding claim, having a hardness of 300 Hv or more, and a tensile strength of 400 N/mm^2 or more.

6. A die casting machine part having a surface which inuse contacts an Al based molten metal, said port comprising:
0.1 to 0.5 wt.% of C;
3.0 to 7.0 wt.% of Si;
5.0 to 18 wt.% of Ni;
0.5 to 8.0 wt.% of Cr; and the balance essentially of Fe.

7. A die casting machine part according to claim 6, further comprising at least one selected from the group consisting of more than 0 to 2.0 wt.% of Mn, more than 0 to 2.0 wt.% of Al, and more than 0 to 2.0 wt.% of Mo.

8. A die casting machine part according to claim 6 or 7, having a martensite phase which has an area ratio of 30 % or more in a matrix metal structure of the casting machine part. structure of the casting machine part.

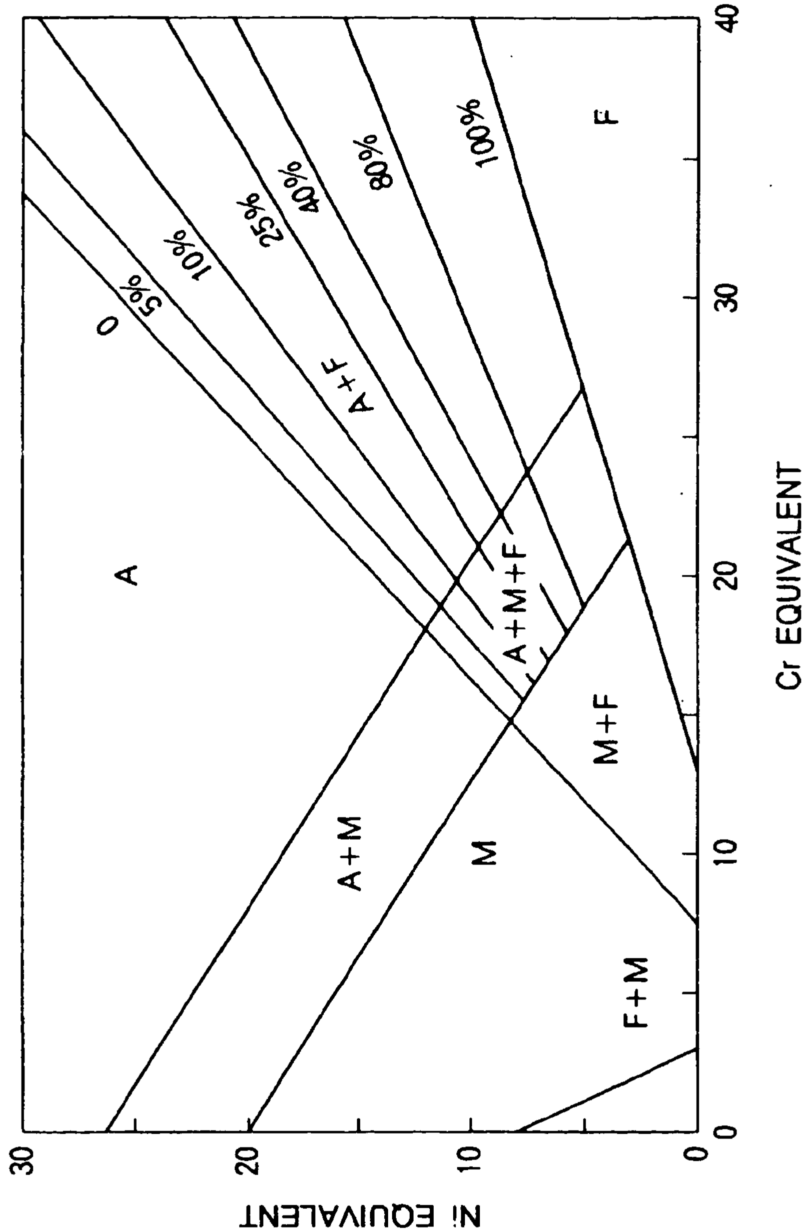
9. A die casting machine part according to any one of claims 6 to 8, having a thermal conductivity of 20 W/m·K or less in a temperature range from a room temperature to 573 K, and a thermal expansion coefficient of 9 to 17 x 10^{-6}/K in said temperature range.

10. A die casting machine part according to any one of claims 6 to 9, having a hardness of 300 Hv or more, and a tensile strength of 400 N/mm^2 or more.

11. A die casting machine part having a surface which in use contacts an Al based molten metal, said part being made of a Fe based alloy comprising 0.1 to 0.5 wt.% of C, 5.0 to 40.0 wt.% of Ni, and 0.5 to 10.0 wt.% of at least one carbide-forming element selected from the group consisting of Cr, Mo, V, Nb, Ta, Ti and Zr,
wherein the die casting machine part has a high density carbide layer formed by selective diffusion reaction with the Al based molten metal in a surface portion which includes said surface which makes contact with the Al based molten metal.

12. A die casting machine for casting an Al based metal, comprising a pair of stationary die and movable die, a pouring port bushing provided in the stationary die, an injection sleeve connected to the pouring port bushing and serving as a teemed molten metal receiver and a pressurizing cylinder, a plunger for charging an Al based molten metal teemed in the injection sleeve, into a cavity of the pair of dies under pressure. and driving mechanism for the plunger,
wherein at least one member selected from the group consisting of the pair of dies, the injection sleeve, and the plunger consists of a die casting machine part according to any one of claims 6 to 11.

FIG. 1



A : AUSTENITE
M : MARTENSITE
F : FERRITE
% : AN AMOUNT OF FERRITE

FIG. 2

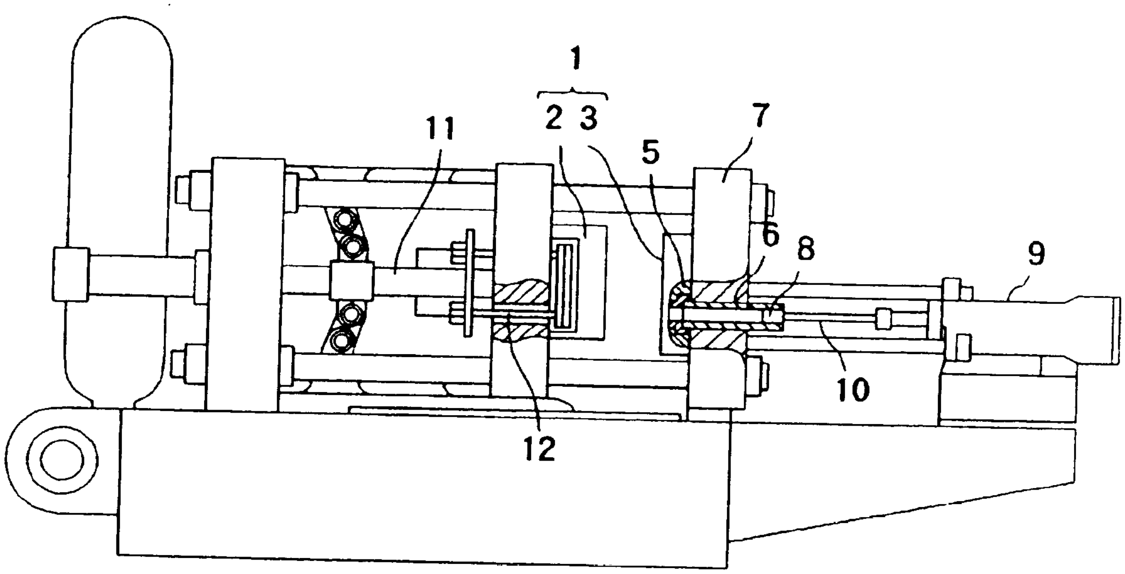


FIG. 3

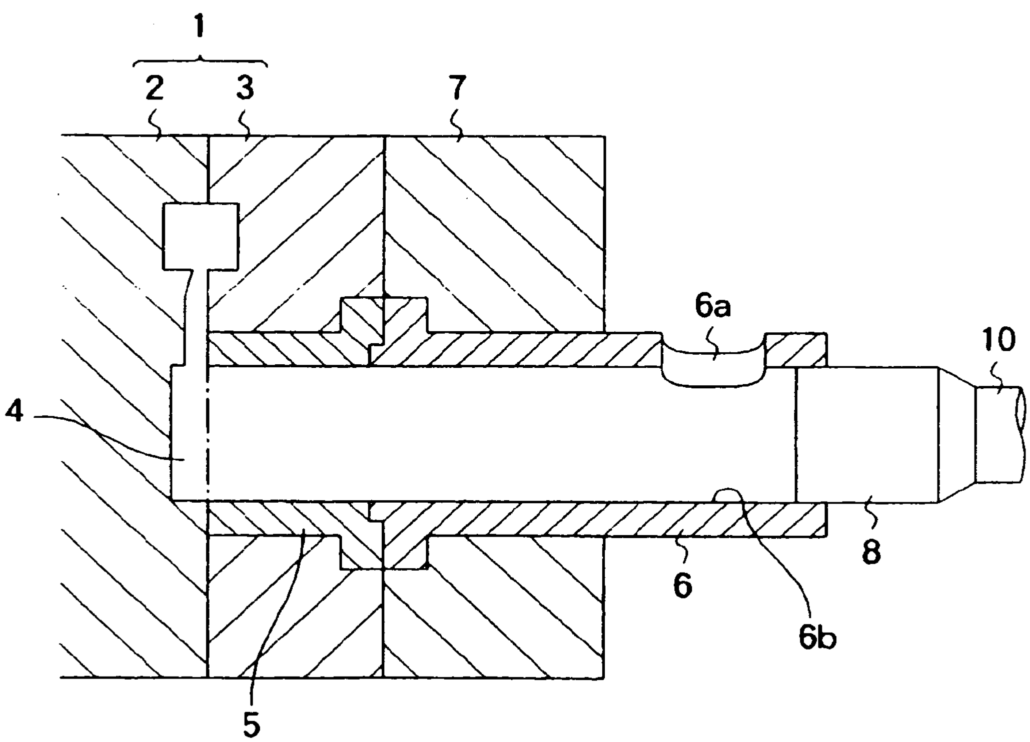


FIG. 4A

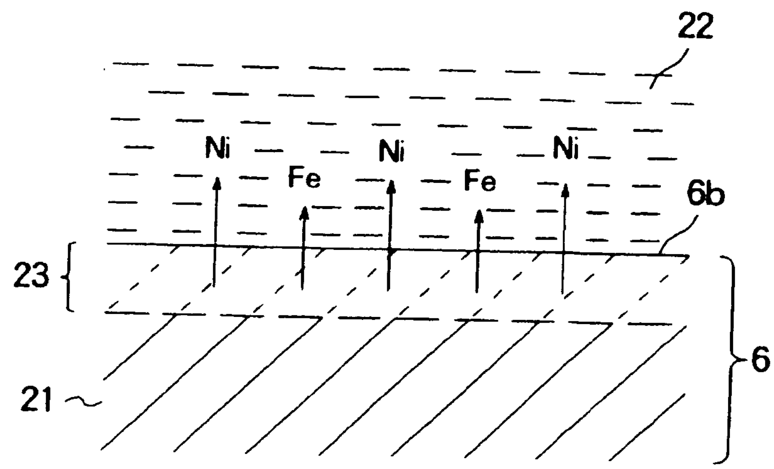


FIG. 4B

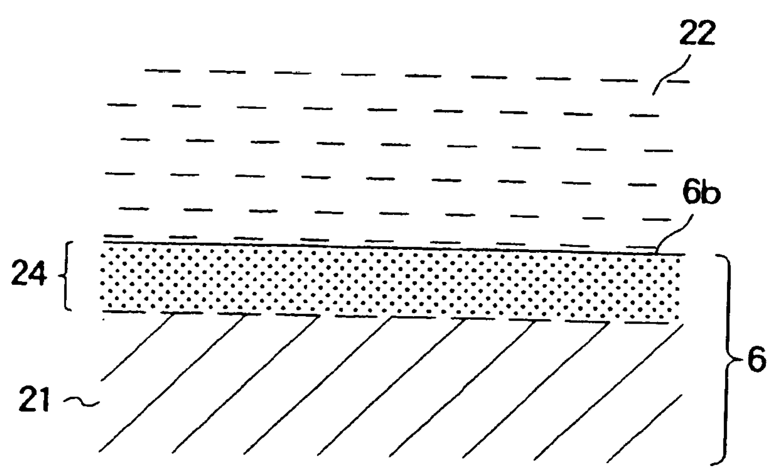


FIG. 5

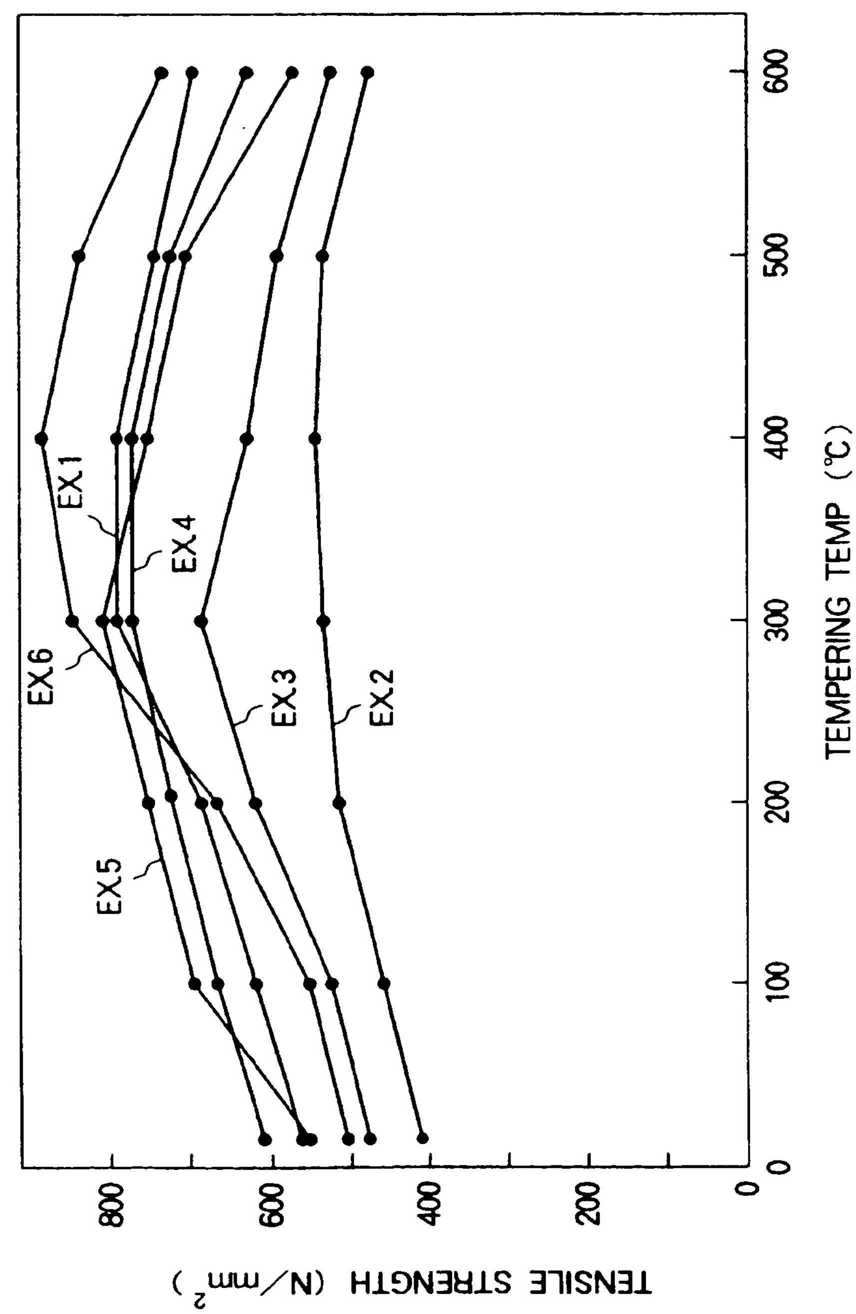

EX.1
EX.2
EX.3
EX.4
EX.5
EX.6
TEMPERING TEMP (℃)
TENSILE STRENGTH (N/mm²)
0
100
200
300
400
500
600
800

FIG. 6

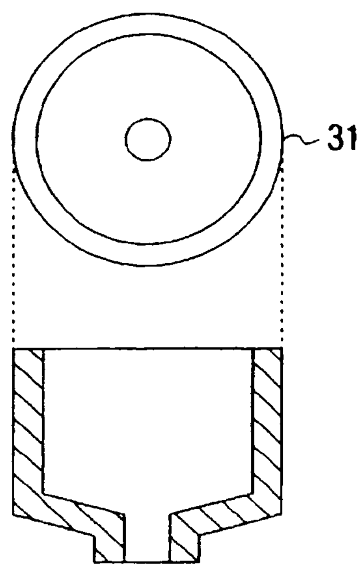


FIG.7A

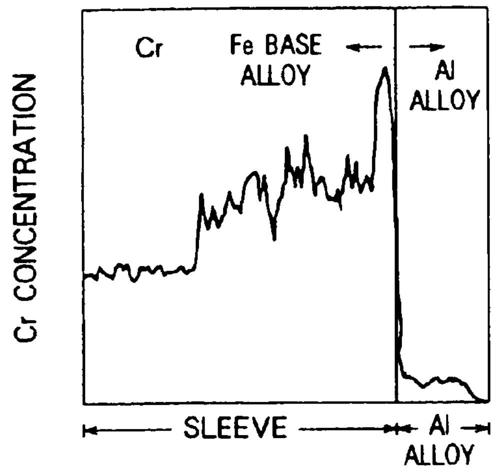


FIG.7B

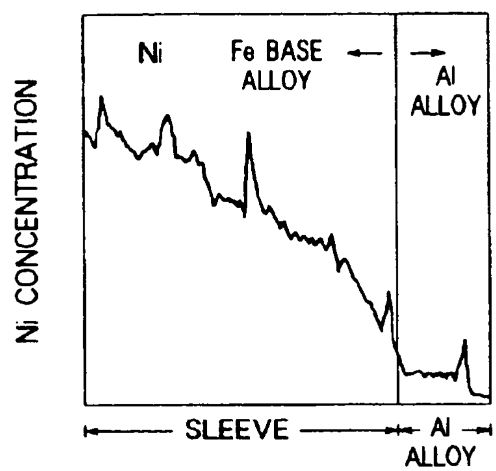
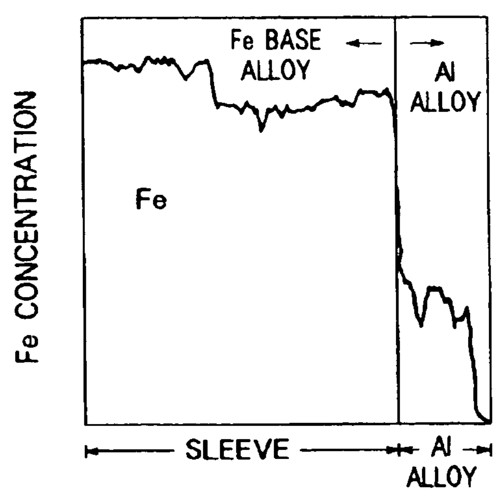


FIG.7C



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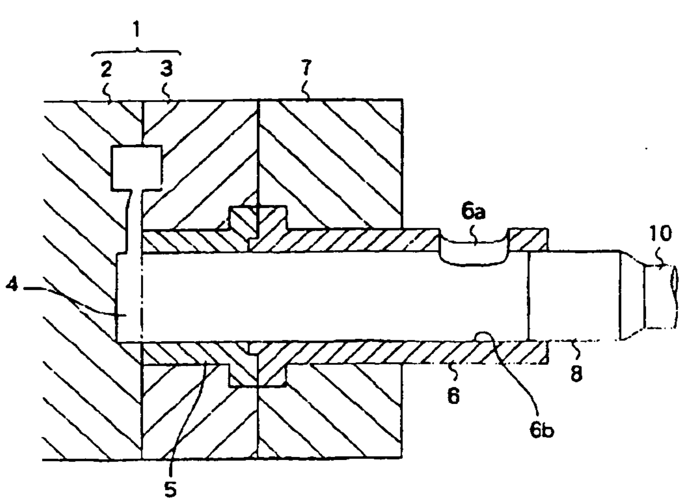
(54) Heat insulating alloy steel and die casting machine parts

(57) A heat insulating alloy steel contains 0.1 to 5.0 wt.% of C, 3.0 to 7.0 wt.% of Si, 5.0 to 18 wt.% of Ni, 0.5 to 8.0 wt.% of Cr, optionally at least one of less than 2.0 wt.% or less of Mn, 2.0 wt.% or less of Al and 2.0 wt.% of Mo, and the balance essentially of Fe. This heat insulating steel has a matrix metal structure with 30 % or more area ratio of a martensite phase. Further, a die casting machine part such as an injection sleeve or a pouring port bushing, having a surface making contact with an Al based molten metal, is made of a Fe base alloy containing 0.1 to 1.5 wt.% of C, 5.0 to 40 wt.% of Ni and 0.5 to 10 wt.% of at least one carbide forming element from: Cr, Mo, W, V, Nb, Ta, Ti and Zr. Such machine part comprises a surface layer portion including the surface making contact with the Al basedmolten metal, formed therein with a high density carbide layer as a dissolution resistance barrier.

FIG. 3



EP 0 798 395 A3

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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 2103

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 148 (C-0928), 13 April 1992 & JP 04 006247 A (NIPPON STEEL CORP), 10 January 1992,	1-5	C22C38/34 B22D17/22
Y	* abstract *	6-10,12	
Y	J.R. DAVIS: "ASM Specialty Handbook - Tool Materials" April 1995, ASM, OHIO, USA XP002034171 * page 252 - page 253 *	6-10,12	
A	DATABASE WPI Section Ch, Week 9219 Derwent Publications Ltd., London, GB; Class M27, AN 92-157809 XP002034173 & SU 1 654 370 A (CARIBONUM LTD), 7 June 1991 * abstract *	6	
A	C.W. WEGST: "Stahlschlüssel" 1986, VERLAG STAHLSCHLÜSSEL WEGST GMBH, MARBACH, GERMANY XP002034172 * page 239 * * page 383 *	6	TECHNICAL FIELDS SEARCHED (Int.Cl.6) C22C B22D

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
MUNICH	21 July 1997	Ashley, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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